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ABSTRACT

The technology explosion in medical education has led to the use of computer models, videotapes, interactive videos, and state-of-the-art simulators in medical training. This booklet describes alternatives to using animals in medical education. Although it is mainly intended to describe products applicable to medical school courses, high-quality, non-animal teaching methods can also be used in graduate medical education. Sections include: (1) Multiple Organ Systems; (2) Cardiovascular Physiology; (3) Clinical Simulators; (4) Pulmonary Physiology; (5) Renal Physiology; (6) Gastrointestinal Function; (7) Acid-Base Physiology; (8) Muscle Function; and (9) Manual Skills. (JRH)

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Alternatives in Medical Education

Peggy Carlson, Editor

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Alternatives In Medical Education

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Edited by Peggy Carlson, M.D.

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Alternatives in Medical Education

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Alternatives
In Medical Education

The technology explosion has hit medical education. Computer models, videotapes, interactive videos, and state-of-the-art simulators are now helpful adjuncts in medical training. In addition, many are being used to replace animal laboratory exercises in physiology, pharmacology, and other disciplines. This occurs at a time when the use of animals is more controversial and more expensive than in the past. Many medical schools have eliminated animal laboratories from their curricula and are incorporating new teaching materials. For those that retain animal exercises it is essential to have an alternate activity for students who decline to participate for ethical or religious reasons. The availability of non-animal options is strongly encouraged by the American Medical Student Association.[1]

Life-like patient simulators—complete with pulses, heart and breath sounds, EKG, and pulmonary pressure readings that respond to the simulated administration of dozens of different drugs—allow trainees to learn, make mistakes, and start over in a realistic context.

Computer models, videos, and high-tech simulators are effective teaching tools. Instructors at the University of Chicago compared student responses to a cardiovascular computer simulation and an animal laboratory and found "the students rated both highly, but the computer-based session received a higher rating."[2] Researchers at the College of Veterinary Medicine in Auburn, Alabama, randomly assigned physiology students to an interactive video system or an animal laboratory. The two groups scored similarly on a multiple choice/short answer test, but the interactive video program proved more time-efficient.[3]

Patient-Oriented Problem Solving (POPS) is a small group teaching tool in which students solve clinical problems as a means of learning basic pharmacology. A study published by the Association of American Medical Colleges found it to be very effective at minimal cost.[4]

Surgical skills are normally acquired by assisting in the operating room. However, some have used animal surgery laboratories in surgical instruction. Stephen M. Tsang, M.D., and his colleagues at Tulane University found that those who learned techniques of laparoscopic surgery in the operating room without an animal laboratory performed just as well as those who also had an adjunctive animal laboratory.[5]

Certainly, non-animal teaching methods work admirably. But will students find them as engrossing as a live animal laboratory? A method used at Harvard Medical School may answer that question. First-year students observed the effects of cardioactive and anesthetic drugs during heart surgery in the hospital operating room. In support of this method, Robert Forstot, M.D., of the Division of Cardiothoracic Anesthesia of Washington University in St. Louis, Missouri, wrote that the operating room is "an ideal venue from which to teach medical students both the pharmacology and physiology that is relevant to their future practice."

It should be said that a great many doctors have been well-trained without the use of computers, videos, or animal laboratories. Lectures, readings, and, ultimately, supervised clinical experience remain the essentials of medical education.

Although this booklet is mainly intended to describe products applicable to medical school courses, high-quality, non-animal teaching methods are also used in graduate medical education. Models are available to teach adult and pediatric intubation, microsurgery, laparoscopic surgery, and many other manual skills. Some Advanced Trauma Life Support courses provide superior teaching using cadavers instead of dogs or other animals. Virtual reality is adding an exciting new dimension for teaching invasive procedures and surgeries. For more information, contact PCRM.

In order to keep this booklet as up-to-date as possible, we welcome information on new products as well as your experiences with those mentioned here.

Purchase inquiries should be made directly with the manufacturer or distributor. PCRM provides this information as a service and is not a product distributor. Prices and availability are based on the latest available information and are subject to change.

Neal D. Barnard, M.D.

1. American Medical Student Association, Preamble, purposes and principles. Reston, Virginia, 1993.

2. Samsel RW, Schmidt GA, Hall JB, Wood LDH, Shroff SG, Schumacker PT. Cardiovascular physiology teaching: computer simulations vs. animal demonstrations. Adv Physiol Educ 1994;11:S36-S46.

3. Fawver AL, Branch CE, Trentham L, Robertson BT, Beckett SD. A comparison of interactive videodisc instruction with live animal laboratories. Am J Physiol 1990;259(6 Pt 3):S11-14.

4. Burford HJ, Ingenito AJ, Williams PB. Development and evaluation of patient-oriented problem-solving materials in pharmacology. Acad Med 1990;65(11):689-93.

5. Tsang SM, Caluda MJ, Steinberg SM, McSwain NE, Flint LM, Ferrara JJ. Laparoscopic cholecystectomy: what's so special? Southern Med J 1994;87:1076-82.

Multiple Organ System Programs

The Laboratory in Pharmacology

Health Sciences Consortium, 201 Silver Cedar Ct., Chapel Hill, NC 27514, (919)942-8731, fax (919)942-3689. Requires PC compatible, MS-DOS 2.0 or higher, 640K RAM, 3.5" disk drive, CGA monitor or better. $150, $105 for HSC members.

This computer program uses high-quality graphics to teach students to apply basic principles of pharmacology to predict drug effects. There are six independent computer-based modules, each requiring approximately one hour of study time: The Dose-Response Relationship (demonstrated on rabbit jejunum); Effects of Drugs on the Isolated Rabbit Heart; Calculating a Blood Alcohol Concentration; Narcotic Agonists and Antagonists (demonstrated on contractions of isolated guinea pig intestine); Effects of Drugs on Autonomic Nervous System demonstrating the effects of certain autonomic agents on an anesthetized dog; and Simulating Blood Glucose Tolerance.

MacPrac

Robert Purves, Ph.D., Department of Pharmacology, University of Otago Medical School, P.O. Box 913, Dunedin, New Zealand, (011)643 479 1100, fax (011)643 479 9140. Requires Macintosh, 1MB or higher, System 6 or 7. $100.

MacPrac is a set of good quality graphic simulations that teach principles of pharmacology, including pharmacokinetics, drug/receptor binding, and clearance. Another section mimics a chart recording of blood pressure in an animal responding to adrenalin, noradrenaline, or isoprenaline with or without alpha or beta-adrenoreceptor blockers to allow the receptor types activated by each agonist to be deduced. Another section mimics a conventional organ bath experiment with a strip of isolated smooth muscle. Here different doses of an agonist can be added and washed out to generate a chart tracing of contractile responses from which dose-response curves may be derived. A surmountable and a non-surmountable antagonist can be added.

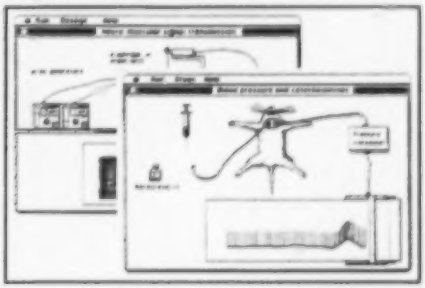
Patient-Oriented Problem Solving

Upjohn Company, 7000 Portage Rd., Kalamazoo, MI 49001, (800)748-0100.

This is a small group discussion format designed to teach problem solving by applying the concepts and principles of pharmacology to therapeutic problems. Each group member is assigned one part of the problem being investigated and serves as a discussion leader as the group works toward achieving a consensus solution to the questions posed by the faculty.

PharmaTutor

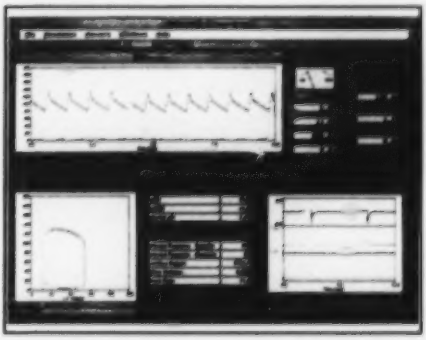
Fund for Research in Alternatives to Animal Experimentation, Biberlinstr. 5, CH-8043, Zurich, Switzerland, (011)01 422 7070, fax (011)01 422 8010. Requires one of the following: Macintosh system with 1MB RAM, Mac Plus or newer model, no hard disk required; PC compatible machine (386 or faster) with Windows 3.0 or better, 2MB RAM, mouse, and EGA or VGA monitor; or ATARIST with 1MB RAM and SM 124 monochrome screen, no hard disk required. $25.



This highly interactive computer program simulates pharmacology experiments on live animals or isolated organs. The five exercises demonstrate: (1) dose-effect relationships on smooth muscle where competitive and non-competitive blockers can be demonstrated; (2) the effects of catecholamines on blood pressure and pulse; (3) mechanisms of neuromuscular signal transmission on an isolated diaphragm; (4) the reaction of the circulation to the effects of acetylcholine and a ganglion blocker; (5) simple pharmacokinetics.

SymBioSys

Medical Multimedia Systems, 1247 E. 70th St., Brooklyn, NY 11234, (800)769-7799. Requires PC compatible 486DX, 33MHz or higher, 8MB RAM, Windows 3.1, VGA graphics and mouse. $395 for single copy, $1,495 for 5-user pack, $5 for demonstration disk.



SimBioSys simulates normal and abnormal function of the coupled heart, lungs, circulation, kidneys, and peripheral systems using state-of-the-art mathematical models to provide real-time, physiological responses to medical interventions. Variables can be viewed in waveforms, digitally, or in trend plots. Hundreds of parameters are shown including systemic and pulmonary compliance and resistance, pericardial fluid volume, ventilatory settings, gas exchange, and infusions of drugs such as norepinephrine and dobutamine. Customized laboratories can be created. User help screens provide basic instruction on physiological concepts.

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Cardiovascular Physiology

Blood Pressure: Controlling Factors Chemical & Physical

Educational Communications, State University of New York, Health Science Center at Syracuse, 750 E. Adams St., Syracuse, NY 13210, (315)464-7929, fax (315)464-7905. Videotape, 59 min., 3/4", call number WG 106 VC no.5, 1979, order number VT7823. $40.00 for rental, $97.50 for purchase.

This videotape discusses the regulation of blood pressure in an anesthetized dog. The baroreceptor reflex is demonstrated as well as the effects of epinephrine, norepinephrine, and isoproterenol. The objective, design, and conclusions of each experiment are identified. The program articulately and concisely explains complex physiologic principles and terminology.

Cardiac Anesthesia Practicum

At some medical schools, students now observe human cardiac anesthesia in the operating room as an excellent way to become acquainted with invasive hemodynamic monitoring, intubation, and cardiovascular drug effects. Cardiac anesthesia involves patient monitoring using arterial lines and Swan Ganz catheters, in addition to EKG, pulse oximetry, and end-tidal CO_2 measurements. The physiologic and pharmacologic effects of many drugs may be demonstrated including narcotics, neuromuscular blockers, anesthetics, beta-adrenergic antagonists, vasodilators, phenylephrine, norepinephrine, dopamine, and dobutamine. In addition, various arrhythmias may need to be treated chemically or with cardioversion or defibrillation. This anesthesia setting is ideal for illustrating pharmacologic and physiologic principles that are relevant to future practices.

Cardiac Pharmacology

University of Texas Medical Branch, Galveston, TX 77550, (409)772-2966. Requires PC compatible with graphics. No charge.

This computer simulation presents the electrical activity of the heart and traces blood volume for the left ventricle. It allows the study of the normal heart, bradycardia, tachycardia, vagal stimulation, PVCs, digitalis intoxication, catecholamines, and re-entry. The student has the opportunity to identify antiarrhythmic agents presented as unknowns, including quinidine, propranolol, phenytoin, and verapamil. This enjoyable simulation provides good graphics and easy-to-follow instructions.

CardioLab

Biosoft, P.O. Box 10938, Ferguson, MO 63135, (314)524-8029, fax (314)524-8129. Requires PC compatible, MS-DOS 2.0, 256K RAM, CGA/EGA/VGA monitor. $199, free demonstration disk.

This instructive program uses good-quality graphics to simulate chart recorder outputs of experiments on anesthetized and pithed animals. Cardiolab allows the "administration" of many drugs including epinephrine, norepinephrine, isoproterenol, acetylcholine, propranolol, atropine, and neostigmine, and can mimic stimulation of vagal and sympathetic cardiac nerves. Effects of blockers wear off at appropriate rates and "overdoses" with agonists or blockers will "kill" the animal. Responses are subject to "biological variation" and are influenced by cardiac compensatory reflexes if appropriate. Cardiolab can provide unknown drugs for characterization by students. A good replacement for cardiac animal labs.

Cardiovascular Interactions

Department of Physiology and Biophysics, Indiana University School of Medicine, 635 Barnhill Dr., Indianapolis, IN 46202-5120, (317)274-8250. Requires PC compatible. $15.00 for mailing and handling charges only.

This computer simulation depicts how changes in vascular resistance, arterial compliance, heart rate and contractility, and venous return affect cardiac output, arterial pressure, and other parameters. The effects of heart failure, systemic and pulmonary hypertension, exercise, hemorrhage, increased intrathoracic pressure, and changes in blood pressure are depicted. The descriptions are very thorough.

Cardiovascular Laboratory Simulation

Charles E. Branch, M.D., Physiology and Pharmacology Department, Auburn University College of Veterinary Medicine, Auburn, AL 36849, (334)844-4425, fax (334)944-5388. Requires PC compatible with Info Window and videodisc player. $500.00, authoring program available at no cost, lesson source code also available.

This interactive videodisc covers cardiac catheterization of the left and right heart, direct reflex effects of autonomic drugs, vagal stimulation, baroreceptor reflexes, atrial and ventricular fibrillation and defibrillation, the cardiac cycle, and other effects. A tutorial review is also presented for those who are new to autonomic physiology. Efficient and effective.

Cardiovascular Physiology

Joel A. Michael, Ph.D., Department of Physiology, Rush Medical College, 1750 West Harrison St., Chicago, IL 60612, (312)942-6426, fax (312) 942-8711. Requires PC compatible, MS-DOS to 5.0, 256K RAM, graphics card (not Hercules). $50.00.

I. PRESSURE/FLOW RELATIONS. This interactive tutorial reviews basic hemodynamic concepts using a simplified model of the systemic circulation, consisting of a heart and five organs arranged in parallel. The exercise consists of an organized series of questions covering static pressures, effects of cardiac pumping, distribution of pressure in circulation, calculation of organ resistances, total peripheral resistance, and local controls.

II. REFLEX. This computer program reviews cardiovascular reflexes using the model described above to cover hemodynamics, blood flow with reflexes, hemorrhage, and muscular exercise.

Cardiovascular Programs

Joseph Boyle, M.D., Department of Physiology, MD-Comp-Edu-Grams, University of Medicine and Dentistry of New Jersey, 185 S. Orange Ave., Newark, NJ 07103, (201)982-4464, fax (201)982-7950. Requires PC compatible, MS-DOS, 640K RAM, VGA or equivalent, CGA graphics. $30.

This computer program is divided into several parts. CYCLE is a graphic representation of the cardiac cycle. HYDROSTATIC PRESSURE is a good graphic representation of oncotic and hydrostatic pressure in the vessels. FLOW allows experimentation with the factors determining flow in a circuit.

Ciresim: A Teaching Exercise on Blood Pressure Regulation

Allen Rovick, Ph.D. and Joel Michael, Ph.D. Department of Physiology, Rush Medical College, 1750 W. Harrison St., Chicago, IL 60612, (312)942-6426, fax (312)942-8711. Requires PC compatible, MS-DOS to 5.0, 256K RAM, graphics card (not Hercules). $150.00.

This computer program is designed to help first-year medical students integrate their knowledge about blood pressure regulation. It consists of eight cardiovascular perturbations including denervated baroreceptor, reduced arterial resistance, increased venous resistance, decreased cardiac contractility, mild hemorrhage, moderate hemorrhage, and increased intrathoracic pressure. The student must predict the effect of each perturbation on cardiac contractility, right atrial pressure, stroke volume, heart rate, cardiac output, arterial resistance, and mean arterial pressure. The student's predictions are then compared with the actual outcome, and errors are discussed.

Ciresyst 2.0

Joseph Boyle, M.D., Department of Physiology, MD-Comp-Edu-Grams, University of Medicine and Dentistry of New Jersey, 185 S. Orange Ave., Newark, NJ 07103, (201)982-4464, fax (201)982-7950. Requires PC compatible, MS-DOS, 640K RAM, CGA graphics. $40 for disk, $10 for backup disk, $200 for site license, $300 for complete set.

In this computer program on cardiac output and blood pressure relationships, the user can alter various parameters such as age, arterial resistance, ventricular muscle mass, reflexes, etc., and observe the effect on ventricular volume, arterial and ventricular pressure, cardiac output, and heart rate. These parameters are graphically plotted. The program includes several preprogrammed conditions such as myocardial infarction, ventricular failure, hemorrhage, several valvular lesions, exercises, and a-v shunts. The last portion of the program provides a series of unknowns drawn from randomly selected conditions.

Classical Experiments in Cardiovascular Physiology

Medical College of Virginia School of Medicine, Box 565, MCV Station, Richmond, VA 23298, (804)828-8319, fax (804)828-8876. Requires Macintosh system with HyperCard 2.1 or higher, OS 6.7 or higher, television monitor connected to videodisc player. $275 for laserdisc and software.

This videodisc contains 37 cardiovascular exercises to help students identify the effects of various drugs and procedures on the cardiovascular system and analyze responses to stress. The program is divided into 3 parts: introduction to the dog lab experiments; performance of experiments (with a normal dog and a vagotomized dog); and completion of a post-test.

Langendorff Heart

Dr. David Dewhurst, Sheffield Bioscience Programs, 11 Robinson Dr., The Park, Pannal Ash, Harrogate, HG2 9DJ, United Kingdom, (011)44 1423 520495. Requires PC compatible. 120 £ for multiuser version.

This highly interactive computer program simulates a range of experiments on an isolated perfused mammalian heart (Langendorff preparation). The effects of drugs (sympathomimetics, parasympathomimetics, cardiac glycosides, and coronary vasodilators) can be demonstrated alone or in combination with a range of antagonists or potentiators. Other experiments demonstrate the effects of ions and of increasing preload on contractile (ventricular) force (Starling Law). The simulated responses (heart rate, ventricular force, and coronary blood flow) are derived from actual experimental data and presented in high resolution color graphics in a form comparable to that of a chart recorder.

MacDogLab

Don Barnes, Ph.D., Medical Foundation of East Carolina University, 525 Moye Blvd., Greenville, NC 27858, (919)816-2749. Requires Macintosh system, 2 MB RAM. $175 for Cholinergic Simulations, $175 for Adrenergic Simulations, $500 for both sets, $1500 for site license, $25 for demonstration disk.

MacDogLab is a computer simulation of the cardiovascular effects of drugs on the anesthetized dog covering cholinergic agonists and antagonists, adrenergic agonists and antagonists, digitalis and antiarrhythmic drugs, and cardiovascular unknowns, with graphic and textual information about the drugs used in the program, and an examination question section. The program is very user-friendly with clear instructions and good graphics. A good replacement for cardiac animal labs.

MacMan

Magnetic Media, Oxford University Press, Oxford Electronic Publishing, 200 Madison Ave., New York, NY 10016, (800)451-7556 or (800)334-4249, fax (212)726-6442. Requires PC compatible, MS-DOS 2.0 or higher, 512K RAM, graphics adapter and display. $150,

$570 for set of all four Mac Series programs (MacMan, MacPuf, MacDope, MacPee), $14 for each manual, demonstration disk available.

MacMan is a computer study of the circulatory system representing the interaction of the heart, the vasomotor center in the brain, intrathoracic pressure, the carotid sinus, vascular flow, and sympathetic function. The program is equipped with clinically relevant symptoms and signs, and can simulate the Valsalva maneuver, hemorrhage, pulmonary edema, etc.

Regulation of the Cardiovascular System

University of Texas Medical Branch, Galveston, TX 77550, (409)772-2966. Requires PC compatible, CGA graphics. No charge.

This program reviews the reflex regulation of blood pressure, including the effects of neurotransmitters and pharmacologic agents. It demonstrates the interaction of various elements in the cardiovascular system such as carotid occlusion, vagal ligation, angiotensin, acetylcholine, norepinephrine, epinephrine, isoproterenol, vasodilators, and blocking agents.

Addendum

Andromeda Interactive Ltd. plans to have CD-ROMs on physiology available in the near future. Contact them at 1050 Marina Village Parkway, Suite 107, Alameda, CA 94501, (510)769-1616, fax (510)769-1919.

Clinical Simulators

CAE Virtual Anesthesiology Training Simulation System

CAE Electronics Inc., P.O. Box 957, Binghamton, NY 13902-0957, (607)779-6021. $185,000.

This state-of-the-art simulator teaches both basic pharmacology and physiology, and clinical medicine using a life-size mannequin, an anesthesia delivery system, and monitoring equipment. The "patient" has palpable pulses, heart sounds, breath sounds, a tongue swelling device, a device to simulate laryngospasm, and monitoring capabilities for pulse oximetry and invasive cardiovascular pressures. It can be used for training in anesthesia, critical care, and emergency medicine, as well as more basic training. A multitude of case scenarios can be created including a blocked airway, laryngospasm, hemorrhage, anaphylaxis, arrhythmias, pneumothorax, hyperkalemia, pulmonary edema, diabetic ketoacidosis, and oliguria. The system can also demonstrate the actions of 70 different drugs, including atropine, dopamine, epinephrine, propranolol, furosemide, insulin, several anesthetics, narcotics, and neuromuscular blockers. Several medical centers in the U.S. and abroad have purchased this system.

Critical Care Simulator and Anesthesia Simulator

Anesoft Corporation, 18606 NW Cervinia Court, Issaquah, WA 98027, (206)643-9388, fax (206)643-0092. Requires one of the following: PC compatible 386, 25 MHz or better, 4MB RAM, 5 MB hard disk, VGA or SVGA graphics, math coprocessor recommended but not required, Windows series available; or Mac II or better, Powerbook 180 or better, 4MB RAM, System 7.0 or higher, math coprocessor recommended but not required, 4MB hard disk series available. $495.

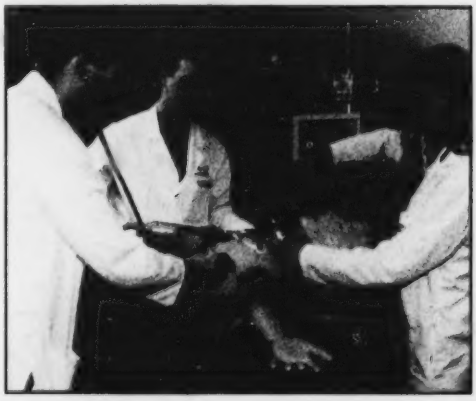
The Critical Care Simulator is an exciting real-time graphic computer simulation that reproduces patient care in an Intensive Care Unit. Twenty different critically ill patients are presented, and the user must manage the airway, ventilation, fluids, and medications. Examples of case scenarios include hemorrhage, chest pain, asthma, and drug overdose. The program reproduces the patient's monitors and simulates the responses of the patients. In addition, the user can obtain information about the patient's physical status such as breath sounds or skin color. About seventy drugs are available for use. The program also includes a consultant system which temporarily suspends the simulated case and provides diagnostic and therapeutic information, describes aspects of cardiovascular and respiratory physiology, and plots plasma concentrations of administered drugs. When the user is done a summary of his/her management can be printed out. Simple "experiments" can be conducted, such as injecting different drugs (epinephrine, atropine, etc.) into different types of patients.

The Anesthesia Simulator is similar to the Critical Care Simulator. It reproduces the anesthesia environment on a computer screen. Dozens of scenarios, such as anaphylaxis, difficult airway, myocardial ischemia, and pneumothorax are available.

Human Patient Simulator

Loral Data Systems, P.O. Box 3041, Sarasota, FL 34230, (813)378-6747, fax (813)378-6995. $180,000.

The Human Patient Simulator is a fully interactive, life-size simulator that can be used to teach physiology, pharmacology and patient management. It has palpable pulses, self-regulating control of breathing, heart and breath sounds, and EKG, and allows monitoring of pulmonary pressures. Sophisticated physiological models of the body systems simu-



late normal and pathophysiological responses to drugs, mechanical ventilation, and other therapies.

Additional features include a self-regulating lung model with physiological gas exchange, a hand-held instructor's remote control, pulmonary artery catheter and thermodilution cardiac output, automated drug recognition system, and a "difficult airway" module. Specific drugs can be injected to show their effects. Fifty-five clinical scenarios are available, including hemorrhage, pneumothorax, cardiac tamponade, hypovolemia, and many others. This simulator was developed by Loral Data Systems and the University of Florida and has been purchased by several medical centers.

Pulmonary Physiology

Ficksyst

Joseph Boyle, M.D., Department of Physiology, MD-Comp-Edu-Grams, University of Medicine and Dentistry of New Jersey, 185 S. Orange Ave., Newark, NJ 07103, (201)982-4464, fax (201)982-7950. Requires PC compatible, MS-DOS, 640K RAM, CGA graphics. $75, $10 for backup disk, $200 for site license, $300 for complete set.

FICKSYST is a computer review of the Fick Principle, which examines gas exchange at the lungs and the tissues. The program examines alterations in gas pulmonary exchange due to changes in ventilation, O_2 transport, or cardiac output. The Fick Principle is then applied to a single organ system so the student can see the results of altering O_2 content, blood flow, or O_2 consumption. These data are saved in a table which the student can examine to help answer test questions. A multi-organ system is presented which allows the student to adjust O_2 consumption and blood flow for each organ and observe the resultant venous O_2 tension. A summary graph allows the user to visualize the entire O_2 cascade from the lungs, arteries, organs, and systemic veins for the current variables.

Gasp: A Teaching Exercise on Chemical Control of Ventilation

Joel A. Michael, Ph.D., Department of Physiology, Rush Medical College, 1750 West Harrison St., Chicago, IL 60612, (312)942-6426, fax (312)942-8711. Requires PC compatible, MS-DOS to 5.0, 256K RAM, graphics card (not Hercules). $250, $300 as a set with CIRCSIM (see p. 10).

This computer program illustrates the chemical control of breathing. Students enter their qualitative predictions of how experimental procedures will affect pO_2, O_2 saturation, O_2 content, $[HCO_3]$, pCO_2, pH, tidal volume, breathing frequency, minute ventilation, and alveolar ventilation. "Experiments" can be conducted by changing the inspired O_2 or CO_2, changing dead space, increasing shunting, and changing hemoglobin concentration, among others. Prediction errors serve as triggers for discussion.

MacLung (Hypercard version of Respsyst)

Joseph Boyle, M.D., Department of Physiology, MD-Comp-Edu-Grams, University of Medicine and Dentistry of New Jersey, 185 S. Orange Avenue, Newark, NJ 07103, (201)982-4464, fax (201)982-7950. Requires Mac SE or better. System 6+, 2 MB RAM. $75 for single copy, $300 for site license.

This program can be used to demonstrate the overall response of the respiratory system to a wide variety of experimental conditions. A tutorial discusses alveolar gas tensions, diffusion, ventilation and perfusion, hypoxia, and gas exchange. The user can alter many parameters including tidal volume, dead space, respiratory rate, cardiac output, pulmonary blood flow, and shunt flow. The effect of these variations on alveolar ventilation, diffusion time, arterial pH, pO_2, pCO_2, and O_2 content, among others, can be measured. Screen graphics change to illustrate the physiological conditions.

MacPuf

Magnetic Media, Oxford University Press, Oxford Electronic Publishing, 200 Madison Ave., New York, NY 10016, (800)451-7556 or (800)334-4249, fax (212)726-6442. Requires PC compatible, MS-DOS version 2.0 or higher, 512K RAM, graphics adapter and display. $190, $570 for set of four Mac Series programs (MacMan, MacPuf, MacDope, and MacPee), $14 for each manual, demonstration disk available.

MacPuf simulates lung and airway function experimentally and clinically, in particular the oxygenation of venous blood and the transfer of gases between blood and tissues. Numerous variables can be manipulated by the student.

Respiratory Programs (PuFT, GasExch, and Mekanix)

Joseph Boyle, M.D., Department of Physiology, MD-Comp-Edu-Grams, University of Medicine and Dentistry of New Jersey, 185 S. Orange Ave., Newark, NJ 07103, (201)982-4464, fax (201)982-7950. Requires PC compatible, MS-DOS, 640K RAM, CGA graphics, Quick Basic (Microsoft). $50.

Set of three computer programs. PuFT calculates predicted values for common pulmonary function tests after patient data are input. A forced vital capacity can be simulated and altered according to variables, and data generated from the FVC can be used to plot pressure, flow, volume relationships, etc. GASEXCH simulates gas exchange in the lungs and tissues using V/Q variations. The results, as well as variable parameters such as capillary density, oxygen consumption, and tissue blood flow, are used to determine tissue oxygen tension. MEKANIX uses graphics and simulations to show the changes in alveolar and intrapleural pressures caused by changes in lung elastance and airway resistance as input by the user. Two lung units are presented as a graph and plot of tidal volume versus time. Ten unknown conditions are randomly presented and the results scored for testing students' understanding. Instructions are clear. The programs are interesting and have good experimental setups.

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Simulations in Physiology: The Respiratory System

Harold Modell, Ph.D., National Resources for Computers in Life Science Education, P.O. Box 51187, Seattle, WA 98115, (206)522-6045. Requires PC compatible, Apple II or Macintosh. $100.

Twelve simulations are included along with an extensive laboratory manual. Demonstrations include the elastic properties of the lung and chest wall, the effects of lung compliance and airway resistance on tidal volume, the work of breathing, alveolar gas exchange, detailed simulations of ventilation/perfusion relationships, and acid-base balance.

Ventrol (Ventilatory Control)

Joseph Boyle, M.D., Department of Physiology, MD-Comp-Edu-Grams, University of Medicine and Dentistry of New Jersey, 185 S. Orange Ave., Newark, NJ 07103, (201)982-4464, fax (201)982-7950. Requires PC compatible, MS-DOS, 640K RAM, CGA graphics capability. $50, $200 for site license, free demonstration disk.

This computer simulation lets the user alter various respiratory stimuli to observe the effects on respiratory frequency and blood gases. Minute ventilation varies each time the program runs, similar to actual patient data. The program demonstrates the response to variations in inspired O_2 and CO_2, metabolic acidosis, several neurological lesions, variations in metabolic rate, and lung diseases. The last part of the program provides unknown respiratory patterns to different stimuli to test the user's knowledge. The program has been used for several years as a "dry laboratory" for medical physiology courses.

Renal Physiology

MacPee

Magnetic Media, Oxford University Press, Oxford Electronic Publishing, 200 Madison Ave., New York, NY 10016, (800)451-7556 or (800)334-4249, fax (212)726-6442. Requires IBM-PC, DOS 2.0 or higher, 512K RAM, graphics adapter and display. $190, $570 for set of all four Mac Series programs (MacMan, MacPuf, MacDope, and MacPee), $14 for each manual, demonstration disk available.

MacPee depicts the interaction of circulation, kidney function, body fluid, and electrolyte compartments. The program reports plasma sodium, potassium, urea, creatinine, albumin, hemoglobin, packed cell volume, right atrial pressure, body weight, and water and solute excretion. The program can simulate conditions such as diabetes insipidus, inappropriate ADH, and Addison's disease.

The Osmotic Diagnostician

Martin Goldberg, Keyboard Publishing, 482 Norristown Road, Suite 111, Blue Bell, PA 19422, (800)945-4551 or (610)832-0945, fax (610)832-0948. Requires Mac Plus or higher,

2 MB of free RAM, 10 MB of free hard disk space. $299, $599 for five workstation site license.

This program is built around a sodium-osmolality map, which plots effective osmolality vs. plasma sodium concentration, indicating those areas that represent abnormalities most commonly encountered in clinical medicine. Users can study normal metabolism and pathophysiology via text and animations illustrating osmoregulation and renal physiology, or they may choose to study various electrolyte disorders, their pathophysiology and diagnosis. They may also enter patient information and receive feedback on the differential diagnosis and pathophysiology.

Simulations in Physiology: The Renal System

National Resource for Computers in Life Science Education, P.O. Box 51187, Seattle, WA 98115, (206)522-6045. Requires either PC compatible with VGA graphics and mouse, or Macintosh system. $300 for set of 6 programs (includes permission to make enough copies to supply student populations).

Set of six computer simulations that provide tutorial and laboratory experiment formats for teaching glomerular filtration, function of proximal and distal tubules, effects of hormones on the kidney, and acid-base control. A laboratory manual provides directions for student "experiments".

Gastrointestinal Function

Effects of Drugs on the Uterus and the Intestine

University of Texas Medical Branch, Galveston, TX 77550, (409)772-2966. Requires PC compatible with graphics card. No charge.

This simulation shows how estrogen affects uterine activity and responsiveness to drugs, and the effects of drugs on intestinal smooth muscle. The effects of oxytocin, ADH, prostaglandin, acetylcholine, epinephrine, clonidine, isoproterenol, phentolamine, propranolol, and atropine are presented. Students can complete a simulated experiment and identify unknowns.

Sheffield Bioscience Gastrointestinal Programs

Dr. David Dewhurst, Sheffield BioScience Programs, 11 Robinson Dr., The Park, Pannal Ash, Harrogate, HG2 9DJ, United Kingdom, (011)44 1423 520495. Requires PC compatible with graphics card (VGA, EGA or Hercules). 120 £ per program, includes postage and site license.

FINKLEMAN is a computer simulation of the Finkleman preparation (an isolated rabbit intestine). The program provides background pharmacology. Additionally, in the Experiments Section simulated contractions, derived from experimental data, are presented on a chart recorder-like display on the monitor.

The user can investigate the effects of adrenergic drugs, electrical stimulation of sympathetic nerves, or the effects of a range of drugs on the response to sympathetic nerve stimulation.

GUINEA PIG ILEUM is a highly interactive program which simulates the transmurally stimulated guinea pig ileum preparation to teach the pharmacology of intestinal smooth muscle and the enteric nervous system. Students control the experiment with easy-to-use pull-down menus. Acetylcholine, clonidine, morphine, naloxone, phentolamine, and atropine can be added to the organ bath alone or in any combination in a range of doses. A "magic" wash can instantly remove all traces of added drugs. Simulated contractions of the gut are displayed in real time in a form comparable to that of a chart recorder and may be used with a graphics printer.

INTESTINAL ABSORPTION simulates experiments on the isolated, everted intestinal sac of the rat, demonstrating the transport of hexoses and amino acids in the small intestine. Students gather data to calculate transport parameters in much the same way they would if they actually performed the experiment.

INTESTINAL MOTILITY is based on the isolated rat colon model. It demonstrates the actions of acetylcholine, carbachol, neostigmine, atropine, adrenaline, and phenolphthalein on basal activity and on the peristaltic reflex response. The program uses high resolution color graphics on a simulated chart recorder display which shows longitudinal muscle tension and fluid propulsion.

Ileum

Biosoft, P.O. Box 10938, Ferguson, MO 63135, (314)524-8029, fax (314)524-8129. Requires PC compatible and printer. $80.00

This computer program simulates laboratory experiments which investigate the effects of agonists and blockers on the isolated guinea pig ileum. The program includes experiments to identify an unknown compound. Random elements are incorporated to simulate the biological variability in response to the same dose of agonist. A permanent record of results can be produced on a normal printer.

Acid-Base Physiology

ABASE: A Program for Teaching Acid-Base Regulation

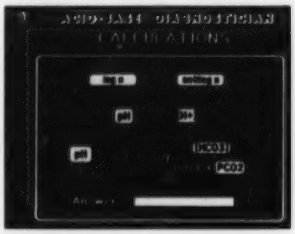
Allen Rovick, Ph.D., Department of Physiology, Rush Medical College, 1750 W. Harrison St., Chicago, IL 60612, (312)942-6567, fax (312)942-8711. Requires Mac SE30, Si or Ci, 2MB (if using System 7), 1MB (if using earlier operating system). $250.

This acid-base computer program consists of 4 tutorial lessons and 7 "problems". The "problems" are conditions that cause acid-base disturbances. The

student must predict the qualitative effect of each disturbance on 5 variables. ABASE checks these predictions and provides instruction when errors are present.

The Acid Base Diagnostician

Keyboard Publishing, Inc., 482 Norristown Rd., Suite 111, Blue Bell, PA 19422, (800)945-4551 or (610)832-0945, fax (610)832-0948. Requires Macintosh, System 6.7 or 7, 2MB RAM, hard disk. $299, $599 for five workstation site license.



This computer program uses text, sound, animation, and sophisticated techniques to illustrate the principles of acid-base metabolism. A teaching module provides basic definitions of acid-base terminology and offers animated presentations of the physiology and pathophysiology of acid-base conditions. A diagnostic module allows users to enter quantitative laboratory data from actual patients and access expert opinion on the likely diagnosis. A casebook contains data on 10 hypothetical patients which may be entered into the program for learning.

ABGame (Acid-Base Game)

Joseph Boyle, M.D., Department of Physiology, MD-Comp-Edu-Grams, University of Medicine and Dentistry of New Jersey, 185 S. Orange Ave., Newark, NJ 07103, (201)982-4464, fax (201)982-7950. Requires PC compatible, MS-DOS, 640K RAM, CGA graphics. $40, $10 for back-up disk, $200 for site license, $300 for complete set.

This computer program presents both a tutorial lesson and a game format. On the tutorial, acid-base terminology is introduced, and renal and respiratory mechanisms of compensation are discussed. The game portion of the program presents abnormal acid-base conditions, and the user gains points by making the correct diagnosis and correcting the acid-base abnormality. Treatment consists of adjusting ventilation and infusing either basic or acidic solutions to correct metabolic imbalances.

ABG's 2.0

MedSoft of Vashon, P.O. Box 60727, Savannah, GA 31420, (912)656-5681, fax (912)234-2215. Requires PC compatible. $249.99 for ABG Teachers, $199.99 for ABG Practice, $174.99 for ABG Test.

This computer program consists of 3 modules: (1) ABG Teachers, a comprehensive interactive tutorial and acid-base evaluation; (2) ABG Practice, a module in which random sets of clinically possible ABG reports are given for practice; each response is evaluated and feedback offered for incorrect interpretations; (3) ABG Test, a module where students can be tested on ABG interpretations and a scoring of the student responses can be printed.

Acid-Base Simulation

Chariot Software Group, 123 Camino de la Reina, San Diego, CA 92108, (619)298-0202, fax (619)491-0021. Requires PC compatible, 1MB RAM, Windows 3.0, mouse and VGA graphics. $40.

Acid Base Simulation is an interactive display of the pathways of respiratory and metabolic acid-base disturbances, and of the responses of a patient by correction or compensation for these disturbances. The operator can work with the Siggaard-Anderson, Davenport, or Goldberg display. Buttons are used to trace the pathways of the primary acid-base disturbances and secondary responses, under the operator's control. The simulation also allows input of pCO_2, pH, or base excess from the keyboard, and can thus function as an acid-base calculator.

Arterial Blood Gases

Electronic Media Division, Williams & Wilkins, 428 E. Preston St., Baltimore, MD 21202, (800)527-5597 or (410)528-4000, fax (410)528-4422. Requires PC compatible. $98.50 for single user, $345 for institutional use.

This computer program reviews arterial blood gas values. One can select one of several patients and be led through the blood gas interpretation as the clinical course unfolds. The user makes clinical decisions on the basis of the blood gas values.

Laboratory Diagnosis of Acid-Base Disorders

Cardinal Health Systems, Inc., 4600 W. 77th St., Suite 150, Edina, MN 55435, (800)328-0180 or (610)835-6941, fax (612)835-7141. Requires PC compatible, MS-DOS 2.1 or higher, 512K RAM. $99.

This computer program helps students diagnose acid-base disorders from standard laboratory data. In difficult cases, comment screens add additional educational information. A differential diagnosis section provides easy access to the multitude of disorders that can contribute to acid-base disturbances.

Understanding Acid-Base Disorders

Division of Audiovisual Education, Duke University Medical Center, Box 3087, Durham, NC 27710, (919)684-3602, fax (919)684-3519. Requires PC compatible 286, 2MB RAM, Windows 3.0, VGA graphics card, color monitor. $30 for one case, $250 for ten-pack, free demonstration disk available.

This award-winning program offers nearly 50 clinical cases for the user to practice evaluating acid-base disorders through multiple choice questions with individualized feedback on every response. Each case relates to basic physiological principles that are discussed in the "Rounds" screen. Users may also probe deeper into basic science concepts explained through colorful graphics and animation.

Muscle Function

Mechanical Properties of Active Muscle

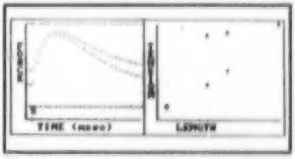
Queue Inc., 338 Commerce Dr., Fairfield, CT 06430, (800)232-2224 or (203)335-0908, fax (203)336-2481. Requires PC compatible, MS-DOS 2.0 or higher, 256K RAM, CGA monitor or better. $70.

These six simulations provide a laboratory-like setting for exploring the mechanical behavior of skeletal muscle. Students set up experimental conditions and observe the results on a simulated isolated muscle. The six open-ended simulations include: Electrical Stimulation; Isometric Contraction; Isotonic Contraction; The Force-Velocity Curve; The Force-Length Curve; and The Biker, which demonstrates the interactions of the mechanisms demonstrated in the other simulations. This program is user friendly and interactive, with clear instructions and good graphics.

Muscle Mechanics: A Computer-Simulated Experiment

Joel Michael, Ph.D. and Allen Rovick, Ph.D., Department of Physiology, Rush Medical College, 1750 W. Harrison St., Chicago, IL 60612, (312)942-6426 or (312)942-6567, fax (312)942-8711. Requires PC compatible, 256K RAM, EGA or VGA color graphics. $50.

In this simulated experiment the user can determine either the length-tension or the force-velocity relationship of a skeletal muscle. A brief question-and-answer tutorial deals with the sliding filament hypothesis for muscle contraction.



Sheffield Bioscience Neuromuscular Physiology and Pharmacology Programs

Dr. David Dewhurst, Sheffield BioScience Programs, 11 Robinson Dr., The Park, Pannal Ash, Harrogate, HG2 9DJ, United Kingdom, (011) 44 1423 520495. Requires either PC compatible or Macintosh with Hypercard. $150 for each program.

MUSCLE PHYSIOLOGY is a high-quality, color, interactive program which simulates experiments on frog gastrocnemius muscle to illustrate properties of skeletal muscle: tetanus, summation, stimulus voltage/response relationships, length-tension relationship, and action of curare. Real experimental data is used to generate simulated muscle contractions which are displayed in a form comparable to that of an oscilloscope.

NERVE PHYSIOLOGY is an interactive program which simulates experiments performed on frog sciatic nerve to illustrate properties of mixed nerves. High-resolution graphic simulations of compound nerve action potentials, derived from real experimental data, are displayed. Experiments include stimulus voltage/response relationships, investigation of refractory period, measurement

of conduction velocity, effects of temperature, and action of a local anaesthetic. Program uses good quality color graphics.

NEUROMUSCULAR PHARMACOLOGY is a program which simulates experiments performed on a sciatic nerve-anterior tibialis muscle preparation to illustrate the action of depolarizing and nondepolarizing blocking agents. High resolution graphic simulations of experimental results (muscle contractions) are presented in accelerated time on a scrolling display to simulate a chart recorder and may be output to a printer. Each experiment compares the action of the 2 types of neuromuscular blocking agents after either intravenous or close arterial administration, in conjunction with an anticholinesterase or a different competitive or depolarizing blocker, in response to tetanic stimulation, or against acetylcholine administered by close arterial injection.

Manual Skills

ANATOMICAL CHART COMPANY, 8221 Kimball Ave., Skokie, IL 60076, (800)621-7500, fax (312)764-0211. Offers models for suture practice, needle decompression of a pneumothorax, central venous cannulation, and adult and pediatric intubation.

ARMSTRONG INDUSTRIES, 575 Knightsbridge Parkway, P.O. Box 700, Lincolnshire, IL 60069, (800)323-4220, fax (708)913-0138. Offers models to teach pediatric and adult intubation, central line placement, cricothyrotomy, intraosseous line placement, and needle decompression of a pneumothorax.

LAERDAL MEDICAL CORPORATION, 1 Labriola Ct., P.O. Box 190, Armonk, NY 10504, (800)431-1055. Offers models for adult and pediatric intubation.

MEDICAL PLASTICS, INC., P.O. Box 38, Gatesville, TX 76528, (800)435-5539, fax (817)865-7221. Offers models for adult and pediatric intubation, cricothyrotomy, needle decompression of a pneumothorax, central venous line placement, intraosseous infusion, and other applications.

NASCO, 901 Janesville Ave., Ft. Atkinson, WI 53538, (800)558-9595. Offers models for manual skills, including adult and pediatric intubation, needle decompression of a pneumothorax, central venous line placement, cricothyrotomy, intraosseous infusion placement, and many others. Specify Health Care Educational Materials Catalog.

Emergency Surgical Procedures

Health Sciences Consortium, 201 Silver Cedar Ct., Chapel Hill, NC 27514, (919)942-8731, fax (919)942-3689. Requires PC compatible, VGA graphics, mouse, video logic DVA-4000 with InfoWindow emulator or Schoolboard II, and Pioneer laserdisc model LD-V4400 or LD-V800. $910 for HSC members, $1,300 for non-members, $22 for preview disc for HSC members, $30 for preview disc for non-members.

This interactive videodisc gives users the opportunity to simulate four emergency surgical procedures—cricothyrotomy, thoracotomy, pericardiocentesis, and thoracic aortic cross-clamping. Users will be able to determine when the procedures are indicated or contraindicated and to identify the equipment used to perform the procedures. Throughout the program, users select the actions, the instruments to be used, and the orientation of the action. They are provided feedback on their choices.

Surgical Training Boards

Ethicon, Inc., Johnson & Johnson Customer Services, P.O. Box 4000, New Brunswick, NJ 08903, (800)255-2500. Offers practice boards for tying and suturing.

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